Instruments

THE MAGAZINE OF Measurement and Control

Vol. 11
NOV.
1938
No. 11

Now! A "9" TAG RECORDER-CONTROL

ON-OFF AND THROTTLING CONTROL MODELS

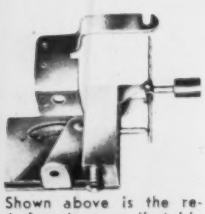
with the surprising pen travel of 3 5/16" on a new 9" chart

PLUS ALL FEATURES OF THE LARGER TAG RECORDER-CONTROLLERS

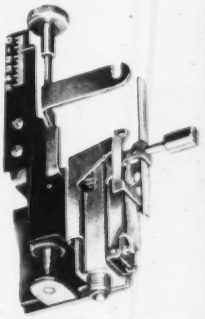
By compacting in a small, beautifully styled case every feature found in the larger instruments, TAG completes a line of Recorder-Controllers with 9, 10 and 12 inch charts. Now it is possible to gain TAG'S unquestioned control precision with either ON-OFF or THROTTLING models, more economically in these smaller instruments with 9 inch charts which provide a pen travel of 3-5/16 inches.

About one-half the size of the standard instrument, these new TAG Recorder-Controllers offer the notable interchangeable tube system. This active element can be replaced readily and need be checked at one temperature only—no necessity of recalibrating all points in the range.

Send for your free copy of Bulletin No. 1178-I which illustrates the new "9" TAG Line of Recorders and Controllers. You will be interested, too, in Catalog No. 1060-I which describes the larger and handsomely styled 10 and 12 inch instruments . . . a request will bring it to you.



Shown above is the redesigned, non-adjustable flapper mechanism in its simplest form . . . the ideal pilot for a great majority of control applications.



Shown above is the adjustable, calibrated flapper mechanism. Its design permits easy adjustment of throttling range to coincide with great apparatus lag.

C. J. TAGLIABUE MFG. CO.

Park & Nostrand Ave's., Brooklyn, N. Y.

TAG LIABUE BROOKLYN N.Y. U.S.A.

escape—

YOUR PROFITS SUFFER...

TOO HIGH OR TOO LOW!

customers. He saved money and helped to stimulate sales.

IN AN OIL REFINERY

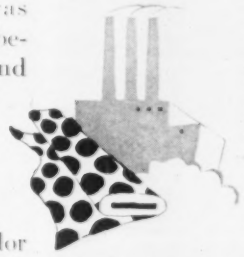
A western refinery decided to install modern, automatic temperature control. Taylor Engineers put in a system with Taylor Dubl-Response Control. *Result:* This automatic control increased the gasoline yield approximately 1% on an average daily run of 4,000 barrels.

IN A PAPER MILL

A large paper mill ran a several weeks' test comparing the efficiency of manual and automatic control of pulp grinders. A Taylor System of Automatic Grinder Temperature Control proved that it could help to increase production 8.9%, reduce conversion costs, and give more uniform quality pulp than before.

IN A TEXTILE MILL

A northern cotton mill wanted to install a more complete system of temperature control. After a survey, Taylor Engineers said, "If you spend $8,000 on control, you will save around $35,000 a year." A Taylor System of Slasher Control was put in. It saved between $33,000 and $35,000 a year.



ANOTHER COTTON MILL

spent $4,000 on Taylor Temperature Control in the Slasher and saved $11,000 in 48 weeks' time. Savings resulted from 70 tons less coal, less raw material, and lower per pound cost of cloth through a 1% production increase.

IN YOUR OWN PLANT

No matter what you produce . . . let Taylor Engineers work with you to relate a Taylor Control System to your needs. We have emphasized temperature regulation in the foregoing cases. But do not overlook the fact that, if there is a question of temperature, pressure, liquid level, rate of flow, or humidity, Taylor can advise you on the system to meet your requirements. For engineering advice and help, see a Taylor Representative or send the coupon direct to Taylor Instrument Companies, Rochester, N. Y. Plant also in Toronto, Canada. Manufacturers in Great Britain—Short & Mason, Ltd., London, England.

THIS PARAGRAPH MAY HELP YOU SAVE MONEY

If there is the slightest doubt in your mind about the efficiency or completeness of the temperature control in your plant now, turn that doubt into action. Fill out the coupon below, tear out this corner of the page, attach it to your company letterhead and mail it today. A request for information about Taylor Control costs you only a 3c stamp. It may result in great benefit to you. There are quick ways to profit through Taylor Temperature Control.

Taylor

Indicating Recording · Controlling

TEMPERATURE, PRESSURE, FLOW *and* LEVEL INSTRUMENTS

Taylor Instrument Companies, Rochester, N. Y.

I am interested in finding out how my plant can benefit from further application of temperature control.

☐ Send me data on your temperature instruments.

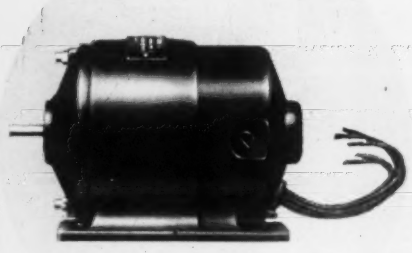
☐ Have a Taylor man call.

(check one or both)

Name _____ Position _____

(Please attach to your company letterhead)

Reliable
REMOTE INDICATION CONTROL



. . . simple with

BENDIX-CORY AUTOSYN
SELF-SYNCHRONIZING
MOTORS!

Remote Control and Indication can provide convenience, safety, efficiency, labor economy—but *only* when accompanied by *reliability*. Bendix-Cory AUTOSYN motors give your Remote Control and Indicating System the reliability and accuracy you must have. They are reasonable in price and possess many superior performance characteristics.

Features of Bendix-Cory Autosyn Type I (Illustrated)

1. Conventional Motor mounting interchangeable with most standard self-synchronizing motor elements.
2. Approximate accuracy: Three degrees.
   (Other types, accurate to .6 degree, are also available)
3. Maximum torque 14.8 inch ounces.
4. Safe continuous operating torque 5.6 inch ounces.
5. Brushes carry no current during synchronism.
6. Enclosed inertia dampener reduces oscillation to maximum of 3 seconds and is adjustable to suit.
7. Dimensions: 3⅝"x3-9/16"x4¾".
8. Weight: 5 lbs., 12 oz.
9. Low current consumption and temperature rise characteristics.
10. Voltage range for accurate and safe operation, minus 20% to plus 10% normal rating.

Complete information on request

BENDIX MARINE PRODUCTS DIVISION
OF BENDIX AVIATION CORPORATION

754 Lexington Avenue — Brooklyn, N. Y.

Instruments
THE MAGAZINE OF MEASUREMENT and CONTROL

VOL. 11 — No. 11

NOVEMBER, 1938

FRONT COVER: Dr. Way using his Surface-finish Microscope on Bearing of 200" Telescope
Courtesy Westinghouse Electric & Mfg. Co.

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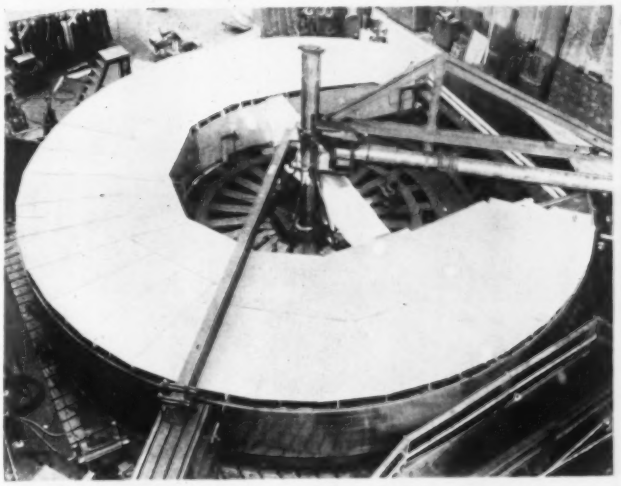
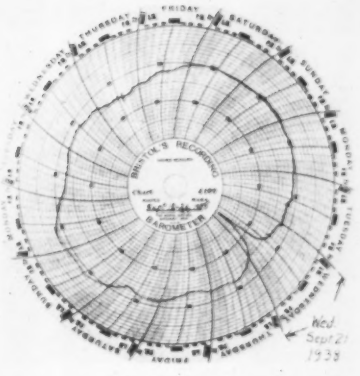
Instruments

THE MAGAZINE OF *Measurement and Control*

M. F. BEHAR, Editor

GRATEFULLY appreciated are readers' letters and cards cheering for last month's special issue on combustion control. . . . We thank also the impish punster who rang the changes on the "more - *power* - to - *Instruments*" theme, but we hadn't and haven't any idea of popping into fields so well tilled by esteemed contemporaries . . . because the province of Instrumentation is barely reconnoitered . . . and its exploration is a fascinating pursuit — as well they know who trace the ramifications of any particular topic . . . for example the subject of instrument bearings which affords not only amazing variety but startling extremes. . . . Largest is the horseshoe bearing for Caltech's 200" telescope; some idea of its size is conveyed by the adjoining picture which shows it being machined at East Pittsburgh. . . . The white roofing is the "sun bonnet" which Westinghouse engineers laid a few inches above it to prevent differential expansions. . . . It is within 0.005" of a perfect cylinder, reports Dr. Stewart Way, Westinghouse research engineer whom this month's front-cover shows measuring the smoothness of the bearing by means of his ingenious surface-finish microscope . . . a microscope he would need also to see the details of the smallest instrument bearings . . . such as jewel types made by several specialists, or those unbelievably tiny ball bearings being furnished by Landis & Gyr and by R. Y. Ferner to instrument and meter firms. One type of instrument bearing thus weighs about fifty thousand million times as much as the other . . . we don't know the exact ratio but we do know that there have been built scales capable of accurately weighing the former, while laboratory balances can weigh several milligrams to a precision of several micrograms. . . . Apropos of extremes, many an *Instruments* reader has occasion to measure megawatts in the morning and to measure microwatts in the afternoon. . . . Nevertheless, the strongest hold that instruments exert on you and us doesn't lie in these 10^{12} measuring ranges: their fascination springs rather from their producing direct and indirect results of enormous value . . . a total value probably incalculable but which will be appraised by representatives of various industries in our January issue . . . a special issue on "What Instruments Do for American Industry." . . . Another source of fascination is that new methods and devices are invented in ever-increasing numbers (as witness our "New Instruments" columns the last eight months). . . . Uncle Sam has taken notice of it and the WPA Project's official report on Instrumentation will soon be out. . . . Yes, its substance will appear in this magazine. . . . Yes, these articles are already on your editor's desk. . . . Yes, the officials wrote them exclusively for *Instruments* — because *Instruments* was the Project's chief source of information! . . . Thirteen solutions and discussions of Instrumentation Forum Problem No. 20 (published in July) were submitted. On August 15 we sent them to the inquirer, asking him to rate them and return them. He hasn't rated them; he hasn't returned them; he doesn't reply. . . . Best we can do for the present is to award Honorable Mentions to all contestants: Emil Anderson, Detroit; R. R. Batcher, Hollis, N. Y.; René Baudry, Pittsburgh; Gordon Clark, Cambridge; Joseph Dauber, Chicago; M. V. Davis, Atlanta; J. W. Fulton, Towaco, N. J.; Foster Gruber, Santa Monica, Calif.; G. F. Laing, Chicago; L. R. Lankes, Rochester, N. Y.; H. Olken, Washington, D. C.; Harold Olson, Minneapolis; E. A. Schmidt, Hazelton, Pa. . . . Having gone through a flood here in '36, we sympathize with New England, recently visited by a disastrous hurricane, as recorded on the barograph chart pictured here, taken at the station maintained by The Bristol Co. in Waterbury, Conn. . . . It is with deep sorrow that we record the death of Colonel Frank W. Roller, president of the Roller-Smith Co., veteran of the Spanish-American and World Wars, prominent engineer and patriot.

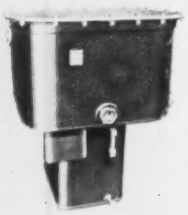




THE MONTH'S NEW INSTRUMENTS

Circuit Breakers

Addition of "Class 50-M" to maker's line of oil circuit-breakers is announced. New breaker, designated "Turblator" by reason of its arc extinguishing contacts, is constructed for subway or outdoors service. Data: 200, 400 and 600 amps.; 7500 volts; 50,000 kva. interrupting capacity; manually operated or automatic. Automatic features may consist of 1, 2 or 3 trip coils and bushing-type current transformers. *Roller-Smith Co., 2552 Woolworth Bldg., New York City.*



Pocket Stack-temperature Thermometer

Designed for use by installation and service men, new Friez Type PT-9 Pocket Stack Thermometer incorporates novel reversible "case handle" (obvious from illustration). Tube material is special high-temperature glass annealed and treated for this use. Standard range is 30-900° F. in 10° divisions. Overall length with tube in case-handle is 7½". Lens-front tubing facilitates reading. *Julien P. Friez & Sons Baltimore and Central Aves., Baltimore, Md.*

Packless H-p. Manometer

Wilcox Manometer for pressures to 1,000 lbs. is of design permitting use of straight tubes which are sealed positively against leakage by synthetic rubber sleeves, thus eliminating stresses in glass. Construction does away with stuffing boxes, provides a compensating seal under pressure. There being no U-bend and only light contact between glass and metal parts, tubes are not subjected to distortion when seal is made. Every part is impervious to gas, oil, gasoline, etc. *Daniel Orifice Fitting Co., Dept. 151-K, 5372 Union Pacific Ave., Los Angeles, Calif.*

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Chlorinated Hydrocarbon Sampler

For determining concentration of chlorinated hydrocarbon vapors in air around degreasing plants, various chemical industries, etc. Consists of: (1) Combustion analyzer in which chlorinated organic is decomposed and resultant hydrogen chloride absorbed in alkaline solution; embodies a calibrated flowmeter and variable resistor; operates on 110 volts a.c. or d.c.; dimensions 6¾" × 8¼" × 27" high; weight 15 lbs. (2) A.c. d.c. motor-driven suction pump. Optional accessories are tripod for combustion analyzer and sample mailing case containing eight glass-stoppered bottles. *Willson Products, Inc., Reading, Pa.*

Dual-range Draft Gage

When resting horizontally as illustrated, new Heath dual-range draft gage measures pressures or drafts from 0 to 0.5" of water, divisions representing 0.01". When gage is held vertically, metal scale at right reads 0 to 10" of water in 0.1"

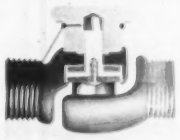
Body is of unbreakable transparent plastic. A new principle is said to eliminate usual reservoir error and to permit cancellation of capillarity error when low pressures are being read. Another feature is that instrument is level when meniscus in inclined tube is at zero on the 0-0.5 scale and metal scales may therefore be permanently fixed in relation to the U-tubes. *Detroit Air Meter Co., P. O. Box 1473, Detroit, Mich.*

Adjustable Resistors

Adjustable wire-wound power resistors have coating of special inorganic cement, may be operated at red heat without blistering, cracking or deteriorating, are available in 10, 25, 40, 60, 80, 100, 160 and 200 watt ratings and in any resistance value from 1 to 100,000 ohms. *Clarostat Mfg. Co., Inc. 285-7 N. 6th St., Brooklyn, N. Y.*

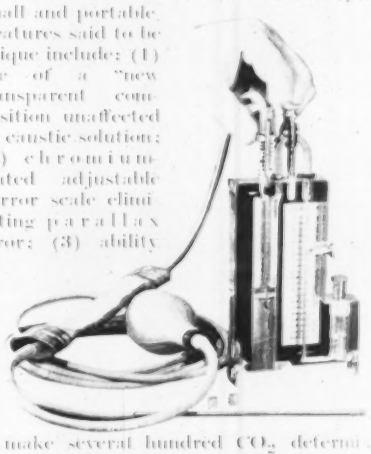
Chatterless Air Valve

Irritating noise and destructive effects of valve hammer in air lines are said to be eliminated by a check valve employing a new principle: moving valve, made of bronze and brass bar stock, is so constructed as to be held suspended by suction created above valve stem by flow of air through siphon hole in valve body. When compressor stops, vacuum above stem is broken and valve returns to its seat. *C. A. Norgren & Co., Inc., Denver, Colo.*



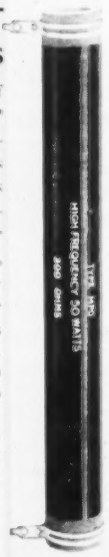
CO_2 Indicator

Designed for use by those concerned with gas-, oil- or coal-fired heating equipment, new Friez Carbon Dioxide Indicator is small and portable. Features said to be unique include: (1) use of a "new transparent composition unaffected by caustic solution; (2) chromium-plated adjustable mirror scale eliminating parallax error; (3) ability to make several hundred CO_2 determinations with one charge of caustic solution. *Julien P. Friez & Sons, Baltimore & Central Aves., Baltimore, Md.*



Ultra-high Frequency Resistors

Suitable for frequencies of 75 Mc. and up, "Type MF High Frequency Power Resistors" find applications as transmitter dummy loads and rhombic antenna terminations; also, due to their non-inductive characteristic, as part of the measuring circuit in high-voltage surge generators and other devices providing steep wave fronts. Five standard lengths 3" to 18½". Power ratings 5 to 150 watts with minimum resistance values of 5 to 25 ohms and a maximum of 1,000 megohms. *International Resistance Co., 417 North Broad St., Philadelphia, Pa.*



LIMITROL

Temperature Limiting Pyrometer

An automatic limiting, heat Shut-Off device designed to shut off the furnace at any pre-set temperature. Fully automatic — all electrical in operation — no mechanical contacts or working parts—simple in construction. Offers a positive method of preventing over-heating of either furnace or furnace load. Its low original and maintenance cost makes it an economical instrument to own.

Complete Data Sent on Request

Wheelco Instruments Co.

1933 So. Halsted St. Chicago, Ill.

S-M-O-O-T-H VOLTAGE CONTROL for A.C. circuits

The Type "TH" Transtat is the new continuously variable auto-transformer regulator . . . the ideal voltage control for a.c. circuits. It offers high efficiency, good regulation, great flexibility and dependable construction at moderate cost. Standard types are available for controlling voltage to single-phase and polyphase loads rated 10 Kva. and smaller, 50 or 60 cycles, 115, 230 or 460 volts. May we send you bulletin 51-1 which contains complete data?

TRANSTAT
VOLTAGE REGULATORS

AMERICAN TRANSFORMER CO.

178 Emmet St. Newark, N. J.

SO_2 Recorder

Elimination of cell corrosion by use of glass cell (Fig. 1 center) and of calibration errors by use of H_2SO_4-removing coke-tower filter (Fig. 1 right) are said

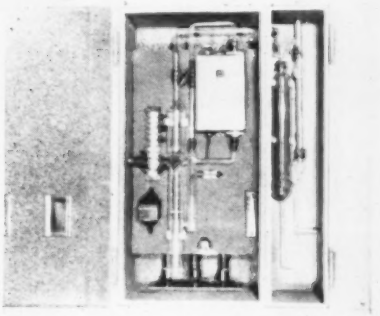


Fig. 1

to make possible, for first time, satisfactory operation of an SO_2 recorder on a gas sample taken immediately after burner with negligible lag. Operator no longer having to wait 10 or 15 minutes to note changes in SO_2 concentration, close burner control becomes attainable. Thermostated cell assembly prevents ambient-temperature error; cell design and constant-head

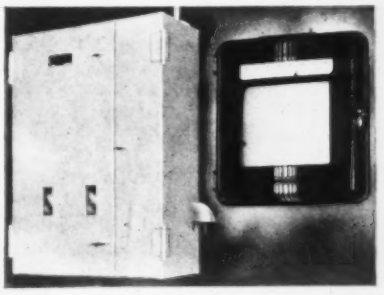


Fig. 2

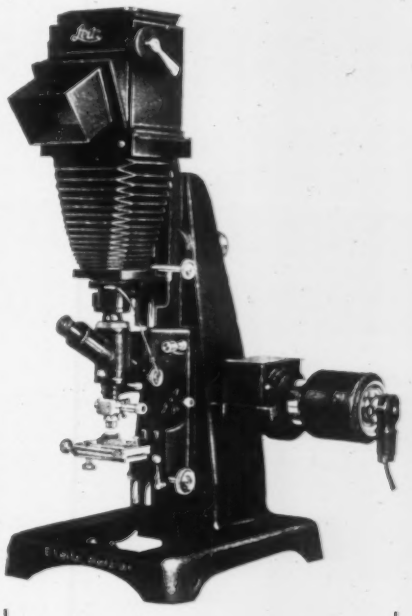
device prevent sample-velocity error; compensated circuits prevent voltage-variation error; use of conductivity method obviates use of chemicals and thereby precludes humidity and reagent-variability errors. A-c bridge circuit requires no batteries, rectifiers, etc. Null-method recorder is available in strip-chart (Fig. 2) or round-chart form. For further details of conductivity method, see item on maker's CO_2 equipment, *Instruments*, May 1937, page 123. *Leeds & Northrup Co., 7655 Stenton Ave., Philadelphia, Pa.*

Photrix Adapter

Providing the equivalent of a camera with built-in exposure meter, Photrix Adapter has been developed for purpose of fastening Photrix Exposure Meter (see *Instruments*, June 1938, page 164) to still or m-p. camera. Adapter fits any camera provided with usual view-finder bracket (on others such brackets can easily be installed). *Intercontinental Marketing Corp., 8 W. 40th St., New York City.*

Leitz

PANPHOT



the UNIVERSAL EQUIPMENT for MICROSCOPIC RESEARCH

. . . and here are just a few of its many features:

Equally convenient for visual observation and photo-micrography.

Equipped with mirror reflex box to facilitate alignment and focusing for photography.

Can be used also for micro-projection, drawing and photo-micrography in transmitted or reflected light.

The Leitz PANPHOT can be used for:

BRIGHTFIELD *(transmitted light)*
DARKFIELD *(from lowest to highest magnification including Plancton)*
REFLECTED LIGHT *(vertical illumination)*
ULTROPAK *illumination*
POLARIZED LIGHT *(reflected or transmitted)*

"Catalogues Nos. 24-V and 25-1 gladly furnished upon request"

E. LEITZ, Inc.

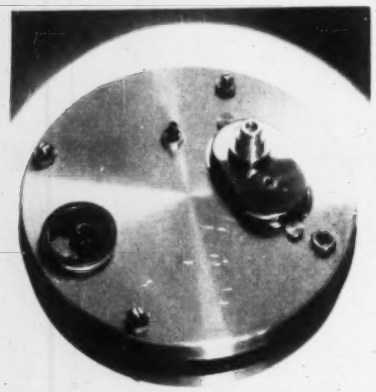
730 Fifth Avenue, New York, N. Y.

Washington . . Chicago . . Detroit

Western Agents: Spindler & Sauppe, Inc., Los Angeles—San Francisco

Recorder Chart Drive

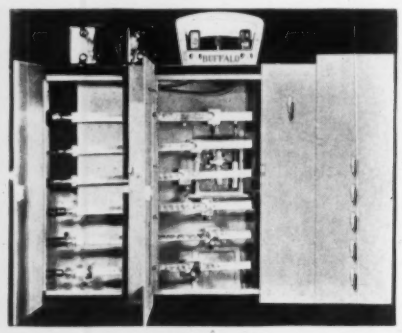
Developed specifically for industrial round-chart recorders, "Macnick Chart Clock" has novel features enabling companies that maintain replacement stocks to effect economies. A "converter turret" makes each unit either a 24-hr. or a 7-



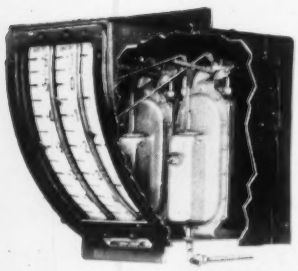
day drive, conversion being effected without tools and without removing drive from instrument case. Although movement is 8-day, there is but one mainspring and one winding stem. Protection against dust and fumes is so effective that drive will operate "perfectly for quite a long time totally immersed in water" and, with a "perpetual oiling system," obviates all need of periodic cleaning and oiling. Escapement being self-starting, usual starter button is done away with. Temperature compensation being complete, no temperature adjustment is needed. Drive being thinner than others and being supplied with adapters, inventories of spares can be minimized. *American Recording Chart Co., 128 Boyd St., Los Angeles, Calif.*

Automatic Batching Scales

A series of industrial scales is announced, embodying various combinations of automatic elements. Illustration shows sequence scales with photoelectric and



mechanical interlock for automatically proportioning several ingredients: this device controls, and is controlled by, weight alone. Should supply of any ingredient fail, operation stops. No timing device is used; interlocks make it impossible to start operation in any but proper sequence or to skip any ingredient. Weights of ingredients are set on scale beams in cabinet; secrecy of formula is maintained, even from operator. *Buffalo Scale Co., Buffalo, N. Y.*



BAILEY MULTI-POINTER GAGES

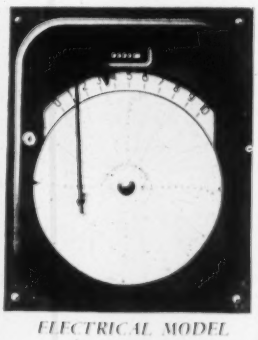
● Bailey Multi-Pointer Gages are made with any number of pointers and any scale combination from one to twelve. The pointers have 10" motion over plainly marked plastic molded scales so that readings can be taken at a distance of 20 feet. Diaphragm actuated elements enable this gage to withstand over-drafts and over-pressures without injury to the unit or its calibration.

All secondary factors such as draft, pressure, temperature, stoker speed and pulverizer feed can be indicated on one Bailey Multi-Pointer Gage.

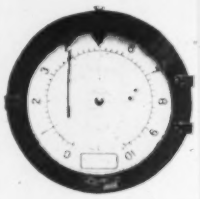
BAILEY METER COMPANY
1041 IVANHOE ROAD · CLEVELAND, O.
Bailey Meter Company Ltd., Montreal, Canada

ACCURATE CONTROL

Distinguished for extreme accuracy and high quality, Cochrane flow Meters are reliable guides for compiling records of consumption, intake, output and variation in the rate of flow of steam, gases, water and other liquids. The Electric Model utilizes the galvanometer null principle.



ELECTRICAL MODEL



MECHANICAL MODEL

The sensitive galvanometer detects the slightest change in rate of fluid flow, unaffected by friction or variations in voltage or frequency. Can be installed any distance from pipe line. The mechanical model develops an extremely high torque, is accurate in design, simple and rugged in construction.

ORIFICE METERS AND TYPE E WEIR METERS

—have the same Cochrane accuracy and simplicity and are highly regarded by users for their particular applications.

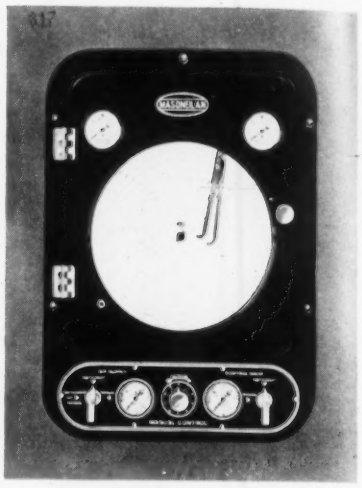
Write for Publication Nos. 2092, 2094, 2096

COCHRANE CORPORATION
3120 N. 17th St. Philadelphia, Pa.

COCHRANE
FLOW METERS

Remote Manual Control from Instrumen

New integral manual control unit provides for remote manual control without leaving front of instrument. The unit enables operator to shift from manual to



instrument control, or vice versa, without disturbing control valve diaphragm pressure, because operator is able to synchronize manual unit output and pilot system output before shifting the mode of control. Shift is made by turning only one knob, without loss of control or upsetting of other factors in the process. New unit is available as integral part of maker's automatic controllers (as illustrated), or as a separate sub-panel for use with instruments already installed. *Mason-Neilan Regulator Co., 1185 Adams St., Boston, Mass.*

Thermal Anemometer

Employing method developed by Dr. Yaglou, new "Thermo-Anemometer" is usable over full range of air velocities employed in industry—from about zero to 6000 f.p.m.—regardless of direction of

air flow. Accuracy is within 2% at all velocities, provided only that user use voltage giving large (25-35°) temperature difference between heated and regular thermometer bulbs. Device is independent of external source of energy for normal use but provision has been made for connection to such where continuous use is desired. Dimension 4¾"×5"×13"; weight 6 lbs. *Willson Products, Inc., Reading, Pa.*

Ultra Thermostat

(AFTER HÖPPLER)

Temp. Constant ± 0.02° C.
Temp. Range 35 to + 250 C.

For
REFRACTOMETRY
VISCOSIMETRY
SEROLOGY

Completely automatic, self-contained. Delivers to the instrument for continuous service 5 liters of constant temperature liquid per minute.

Bulletin HT-254 on request.

JENA KPG ALL GLASS STIRRER

(For Vacuum or Pressure)

Replaces clumsy mercury seal. No supplementary seal or stuffing box needed. Pressure differences as great as 100 mm. of mercury between inside and outside of flask cause no leakage. Also keeps out impurities.

Apparatus, as supplied, consists of bearing and shaft precisely fitted to each other. Inner surface of the bearing tube is accurate within ± 1 to 2 microns.

Leaflet JS 262 on request
Available at leading laboratory supply dealers

FISH-SCHURMAN CORPORATION
250 East 43rd Street New York City

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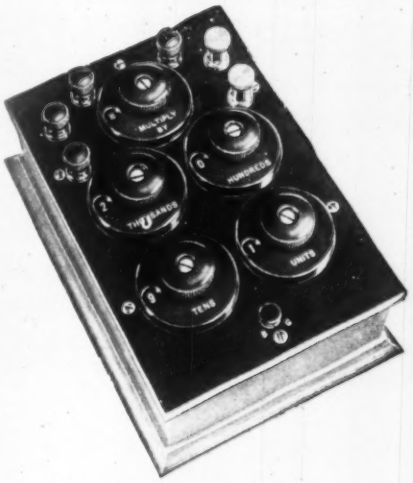
Jena Glass Works, Schott & Gen.

Fish-Schurman

WHEATSTONE BRIDGE



A high-grade laboratory instrument containing 4 rheostat decades of 9 coils each, total resistance 9999 ohms, and a ratio dial affording 7 ratios, .001 to 1000. Rheostat coils are guaranteed accurate to within 1/10%, ratio coils to within 1/20%.

Described in Bulletin 100 which also describes Rubicon resistance standards, shunts, resistance boxes and several types of Wheatstone and Kelvin Bridges.

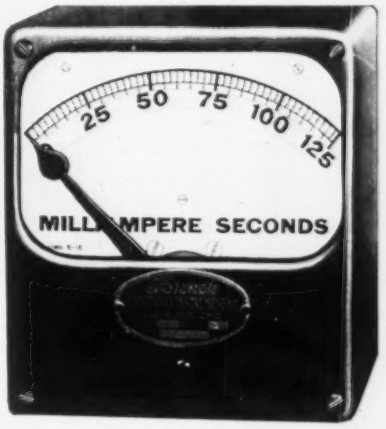
RUBICON COMPANY
Electrical Instrument-Makers
29 North Sixth St. Philadelphia, Pa.

Fuel-Air Ratio Indicator

Announced as an "unusual and practical development in instrumentation" direct-reading Askania Ratio Meter consists of two flow meters, one for air and one for gas, with pointers so arranged to cross in the chart area that their intersection indicates the relation between the two flows. Coincidence on the vertical zero line shows that a neutral flame is being maintained. If pointers cross in the area to the right, intersection shows percent of excess air. Conversely, if pointers cross in left area, it shows air deficiency. New ratio meter may be used on all types of heating apparatus whether equipped with automatic fuel-air ratio control or manually operated. Crossing-pointer principle may be adapted to other conditions to show the relationship between two variables. *Askania Regulator Co., 1005 S. Michigan Ave., Chicago, Ill.*

Milliampere-second Meters

A series of thirty single-, double- and triple-range milliampere-second meters brought out for X-ray work, etc., includes 8¾" round-case and 5¾" × 5½" rectangular-case meters, for a-c. and for d-c. applications, in six ranges with maxima from 10 to 150 m-a-s. All meters register quantity by integration, regardless of rate. The d-c. type, when used in the high-tension rectified part of an X-ray circuit, must be completely insulated from ground; the a-c. type can be placed in the grounded side of the secondary and located on control board of X-ray apparatus. *Hickok Electrical Instrument Co., 10513 DuPont Ave., Cleveland Ohio.*



Now... ANALYZE FLUE GASES FOR CO_2 BY THE THERMAL CONDUCTIVITY METHOD

THE ENGELHARD FLUALYZER

Here is a small portable CO_2 Indicator or CO_2 and Temperature combined if you prefer it, that makes Flue Gas Analysis very easy. It does not require a trained chemist since readings are obtained directly by drawing the gas through the cell. No matter what your problem is, if it requires CO_2 analysis consider this instrument. It may be used on the small domestic installation or on large industrial boilers. Half the time and half the effort are required.

Send for Bulletin No. 700

CHARLES ENGELHARD, Inc.
90 CHESTNUT ST. NEWARK, N. J.

Manufacturers of Pyrometers, Resistance Thermometers, Exhaust Gas Analysers, Flue Gas Analysers, Thermocouples.

Remote-reading System

An optical system is announced whereby remote sight boxes, instrument dials, etc. are viewed through a conveniently-located telescope and a series of mirrors.

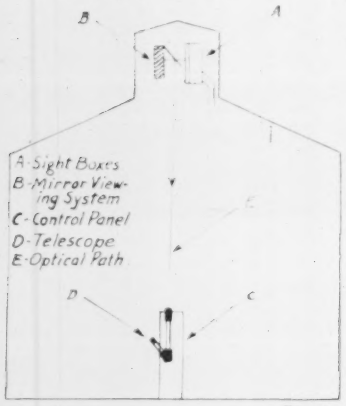


Fig. 1

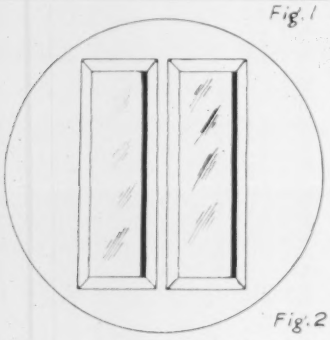


Fig. 2

Fig. 1 shows application to a benzol plant where conditions preclude the use of any other type of telemetering system: sight-boxes *A* are actually 36 ft. above control cabinet but their apparent distance through reading telescope *D* is 30". Moreover, they appear to be side by side as shown in Fig. 2. New system, though originally devised for benzol plants, is suitable for many other applications, not only where hazards are to be avoided but where certainty of readings is required. *Perkin, Elmer & Moffitt, 50 Broad St., New York City.*

Chlorine Feed Control

"Automatic Vacuum Controlled Chlorine Sterilizer" for waterworks and sewerage applications continuously meters and feeds chlorine gas as a solution, is described as "a Rota-meter (or Rota-relay for large capacities) automatic gas shut-off vacuum sterilizer." Design features include: visible control of gas flow; capacity range ratios from 1:[illegible]; only two moving parts; single-valve control located directly below visible [illegible]; automatic gas shut-off should water pressure fail through pump stoppage, line leak or other causes; electrically operated water shut-off synchronizing on and off of sterilizer with that of pump; complete vacuum feed; separation of water and gas lines; water-sealed gas vent; [illegible] siphon break that prevents back flooding. Is available in tower (Fig. 1) or panel (Fig. 2) forms. *Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.*

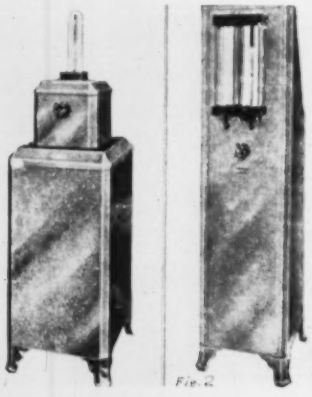
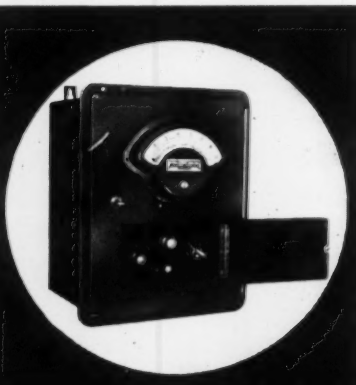


Fig. 1 Fig. 2



BECKMAN ANNOUNCES A
Completely Automatic
pH INSTRUMENT!

★ This new Beckman development, operating on 110 V. AC power, *continuously and automatically* indicates pH on a direct-reading dial. Will operate ANY standard Recording Potentiometer or Controller without special accessories or calibration. Sealed and Shielded Glass Electrodes can be installed directly in vats and tanks. No stray current effects...no sampling device required. High Beckman accuracy assured by Automatic Temperature Compensation.

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holds the reins of **ECONOMY** and **EFFICIENCY** in every Industrial and Scientific activity.

GALLET TIMERS
(as well as GALCO, SECURITY and GUINAND TIMERS)
set the world's standard for lasting dependability

Complete Catalog 6F FREE

JULES RACINE & COMPANY
20 WEST 47TH STREET, NEW YORK

Viscosimeter

After four years' use in several large plants, Brookfield "Synchro-Lectric" drag type indicating viscosimeter is now being manufactured for the market. Illustrations show new standard model, by which a special Telechron motor drives the spindle at constant speed. Range dial (see Fig. 1) is graduated in centipoises.

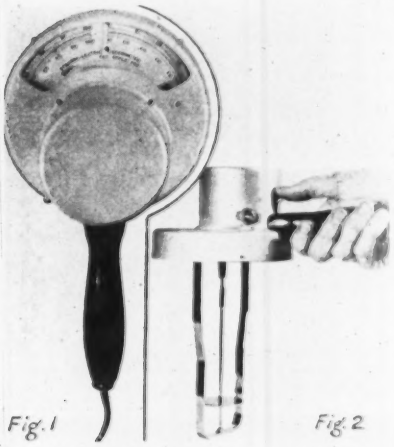
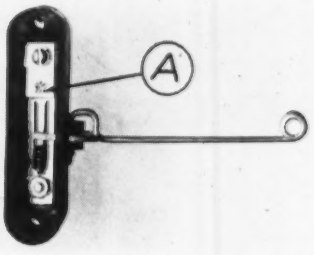


Fig. 1 Fig. 2

A series of six spindles (Fig. 2 shows a cylinder-and-disk type) provides a series of ranges extending to 200,000 centipoises when used in the standard model. Special models are available for high and low extremes. Standard models are calibrated to National Bureau of Standards oils and are accurate to 1%. Instrument may be used wherever 60-cycle current is available, may be held by hand, clamped in ring stand, etc. *Brookfield Engineering Labs., Sharon, Mass.*

Float Switch

Illustration shows top view of new SR float switch. Circuit is opened and closed at "A" by a toggle actuated by a lever protruding 2" from side of molded



plastic housing which measures 2½" long, 1⅝" wide and ¾" high. Switch will handle up to 10 amps. a.c. *Soreng Manegold Co., 1201-05 Clybourn Ave., Chicago, Ill.*

Surface Temperatures

The "Alnor" Combination Pyrocon

Ideal for rolls, molds, plates, platens and plastic material temperatures.

Write for bulletin.

Illinois Testing Laboratories, Inc.
142 W. Austin Ave. Chicago, Illinois

The All Purpose
AIR VELOCITY METER

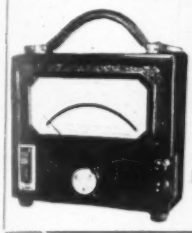
"Alnor" Velometer

Instantaneous Direct Reading

No Timing
No Calculations
Write for Literature

ILLINOIS TESTING LABORATORIES, Inc.
142 W. Austin Ave. Chicago, Illinois

NEW "ALNOR" PORTABLE PYROMETER



Shock Resisting, Floating Movement, Has 5" Mirrored Scale Metal Case.

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ILLINOIS TESTING LABORATORIES, Inc.
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Self-Generating
Photo-Electric Elements
Ultra Sensitive
Permanently Stable
Unlimited Life

Great variety of sizes and shapes
Round cells from 3/8 to 2 5/8" Dia.
Mounted or unmounted

NEW: * * *
Foot Candle Meters of unequalled sensitivity up to 1 1000 ft.-cdl.

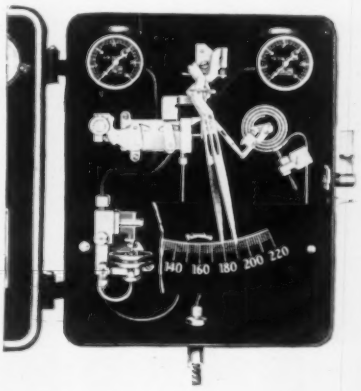
PHOTRIX
UNIVERSAL PHOTOMETER
Single and multiple cell models

PRICES From
$37.50 Up

DR. F. LOEWENBERG
10 East 40th St. New York, N. Y.

Indicating Controllers

"Direct-Set" line of indicating controllers for temperature, pressure and other applications calling for a pressure-spring type measuring element, is announced.



Apart from absence of a recording mechanism, new controllers are generally similar to recorder-controllers announced last month (*Instruments*, Oct. 1938, page 263). Among features are a safety link for over-range protection, interchangeable tube-systems, and all important parts of stainless steel. Controllers are available for "on-off" and for throttling modes of control the latter being provided with a sensitivity adjustment.

C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.

Level Controller

Said to be versatile in its applicability, new "Faratron" level signal or automatic level controller has no moving parts within the tank or bin, its primary measuring element being an electrode or antenna. For high-low applications a pair of antennas (Fig. 1) is used; for special purposes a greater number may be installed. A capacitance principle being utilized, reservoir or bin may contain liquid, paste, powder, granular material, etc. Variations in temperature or pressure do not cause malfunctions. Signalling or controlling instrument may be installed at any distance up to 125 ft., may be any of maker's standard Faratron Controls such as "Model 1-FL" (Fig. 2).

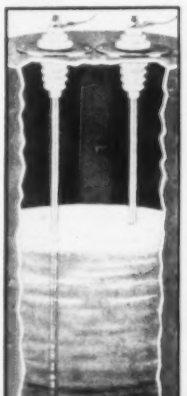


Fig. 1

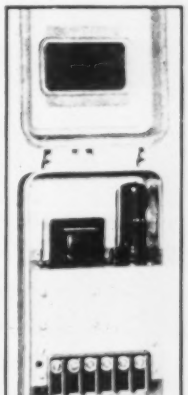
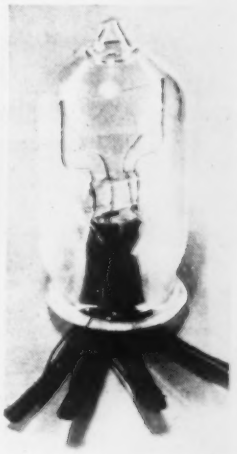


Fig. 2

Lumenite Elec. Co., 305 South Dearborn St., Chicago, Ill.

Vacuum . . . Thermocouples

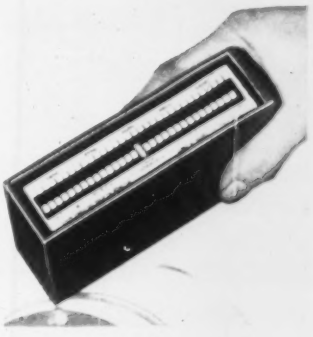


Ranges from 1 milliampere to 10 amperes, in either contact or separate heater types. Prices from $3.00, quantity discounts.

Write for Bulletin "A"

AMERICAN Electrical Sales Co. Inc.
67 E. 8th St. New York, N. Y.

"FRAHM" HAND TACHOMETER



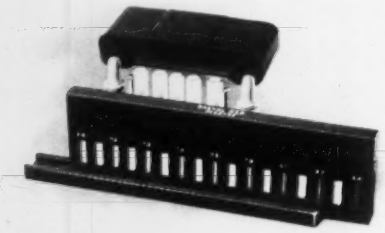
The Frahm Vibrating Reed Tachometer requires no contact with the rotating element or any belts, gears or electrical connections.
Imposes no load.
Operates in any position.
Does not have to be oiled.
Cannot be injured by overspeeding.
Various ranges from 900 r.p.m. to 80,000 r.p.m.

Write for Bulletin 1500-I

JAMES G. BIDDLE CO
ELECTRICAL INSTRUMENTS
1211-13 Arch Street Philadelphia, Pa.

pH Slide Comparator

New slide comparator outfit for colorimetric determination of pH, chlorine and phosphates is molded entirely from plastic. Radical changes in design have re-



duced weight and improved appearance, durability and ease of handling. All pH, chlorine and phosphate values, as well as indicator names, are engraved in white on plastic slides. Outfit, including the slide is 10" long, 2½" wide, 4" high; weighs 1½ lbs. Each slide contains 9 color standards alternating with ampoules of distilled water. All color standards are guaranteed to maintain their accuracy for 5 years. One base can be used with any number of color standard slides. *W. A. Taylor & Co., 852 Linden Ave., Baltimore, Md.*

Rectifiers for Cathodic Protection

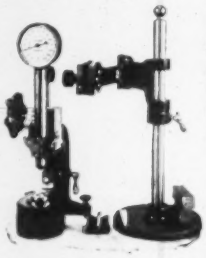
To counteract electrolysis of underground pipe lines, cables, etc., new copper-oxide Rectox rectifiers developed for cathodic protection have a rating range from 3 to 50 volts, 1 to 125 amps. d-c. output. They consist of necessary Rectox units for desired rating, a two-winding transformer, disconnect switch, and terminal board, in either an outdoor or an indoor cabinet. They required no maintenance; and no attention beyond occasional check of output which is required anyway due to seasonal variations in soil and coating resistivity. They operate without noise and without causing radio interference. *Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

Bottom Hole Sampler

For taking oil and gas samples under pressure from the bottom of a well, Warusco Bottom Hole Sampler is recommended for pressures up to 5,000 lbs./in.²; takes a sample of approx. 250 c.c.; measures 1¼" O.D. by 5½' long; is made of stainless steel throughout, with valves, valve seats and wire line heads hardened. A thermometer joint with maximum-reading thermometer can be supplied to measure the temperature at which the sample is taken. Makers furnish also all test equipment for determining physical properties of the samples. General routine set-up consists of two volumetric mercury pumps, expansion bomb, water jacket, water circulating pump, bomb shaker and thermostatic controlled water heater. *Walter Rasko & Co., Inc., 2552 Bellaire Blvd., Houston, Tex.*

HARDNESS TESTING...

done WITH NO MENTAL HAZARDS. The SCLEROSCOPE has done it for the past 30 years.



In general use for specification purposes. Simple, sturdy. Comparatively inexpensive.

Illustrated bulletins free.

The Shore Instrument & Mfg. Co., Inc.
9025 Van Wyck Avenue, Jamaica, N.Y.

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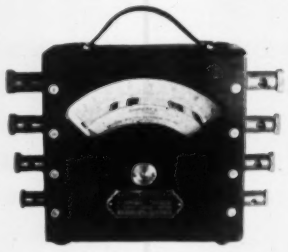
Heed Their Appeal

KNOPP
Multirange A. C. Ammeter



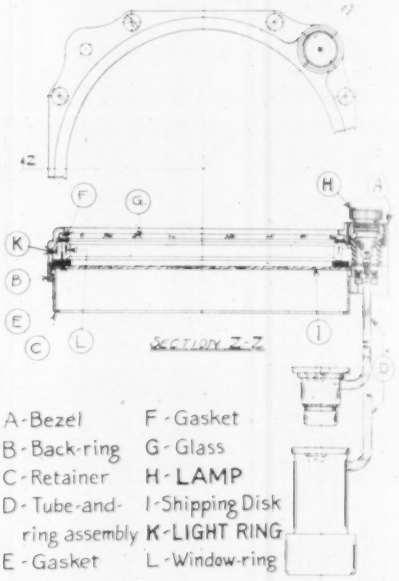
Entirely Self Contained—Meets Maximum Test Requirements

7 Ranges 2 to 200 Amperes
Weighs 5½ Pounds 5½" Scale
Accuracy Within 0.7%

Western Electro-Mechanical Co.
INCORPORATED
OAKLAND, CALIFORNIA

Individually Illuminated Instrumen[ts]

Developed for aircraft instrumen[ts] but suitable for plant uses, "Pioneer [Ring] Light System" provides evenly-dist[ributed] diffused illumination of pointer and dial with no perceptible glare. White light is conducted, from a "grain-of-wheat" lamp in corner, around periphery of dial [by a]

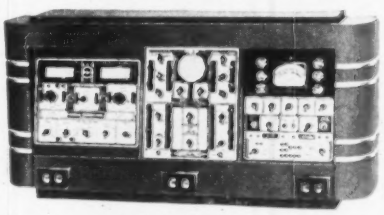


A-Bezel F-Gasket
B-Back-ring G-Glass
C-Retainer H-LAMP
D-Tube-and-ring assembly I-Shipping Disk
E-Gasket K-LIGHT RING
L-Window-ring

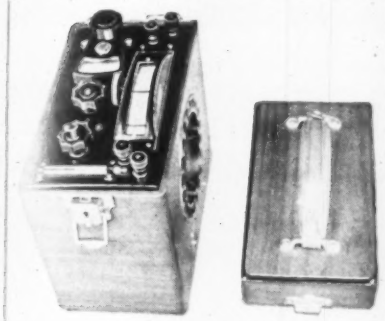
ring of molded plastic, enters pressure-tight case through a window ring also of molded plastic. Thus lamp is maintained outside pressure-tight seal and may be readily changed in flight without affecting calibration of instrument. Light-ring and window-ring are of Bakelite polystyrene. Apart from illumination feature, new case construction obviates need of sealing compounds and hand-fitted snap rings; coverglass is held in place by means of a separable bezel ring retained by eight screws accessible from face of instrument; pressure seal is maintained by gasket under coverglass. *Pioneer Instrument Co., Inc., 774 Lexington Ave., Brooklyn, N. Y.*

Radio Service Panel

Forty-four inches wide and impressively illuminated by concealed Lumilines, "Show Late" has been developed to aid radio dealers and servicemen sell tube



and set service; is available in various combinations of maker's own testing instruments, also with one or two testers and blank panels for future use. *The Hickok Electrical Instrument Co., 10514 DuPont Ave., Cleveland, Ohio.*



"Sales Mean Jobs"

WHEELCO

Portable Potentiometer

with removable cover

- Specially designed for field and laboratory use.
- Hand drawn millivolt scales, or temperature scales in Fahrenheit, Centigrade, or both.
- Accuracy and sensitivity is far higher than any temperature calibrated pyrometer.
- Made in four different models, having special equipment for different classes of service work.
- Complete data and information furnished on request.

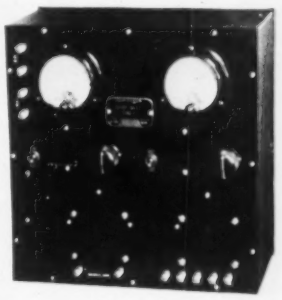
Write for Catalog "G"

Wheelco Instruments Co.

1933 So. Halsted St. Chicago, Ill.

Cycle Counter or Chronoscope

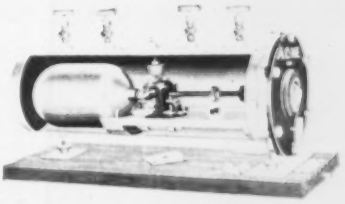
For timing the operations of welders relays, contactors, X-ray apparatus, etc. new "RayTimeR" registers on a scale the time during which an a.c. circuit is



energized. Range is $\frac{1}{120}$ sec. to 30 secs. Scale may be calibrated in cycles or seconds. Accuracy is ± 5%. Only moving part is the pointer; only maintenance is replacement of vacuum tube which is a standard radio type. Illustration shows dual type unit wherein two "RayTimerRs" are juxtaposed for convenience. *Raytheon Mfg. Co., 555 Willow St., Waltham, Mass.*

Meter Book Cover

Public utilities in Central and South America having found that ordinary meter-reading record book cover materials did not withstand combination of climate and handling, there has been developed a cover to stand up under extreme conditions. Metal covers being ruled out as electrical conductors, designers turned to a Bakelite laminated material. New cover is said to be adopted by utilities all over the world. *The Federbush Co., Inc., 51 Seventh Ave., New York City.*



The AC-ME

Gas Gravity Balance

A portable instrument for determining the specific gravity of any gas.

Results obtained are dependable and accurate as the instrument is designed on fundamental laws of Physics.

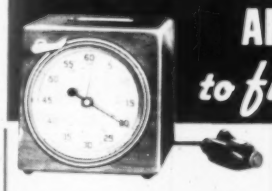
Spring Suspension is used for the Balance Beam which can be locked from the outside.

Write for description.

The Refinery Supply Co.

631 E. 4TH ST. TULSA, OKLA.

There's no FUMBLING AROUND to find the



STANDARD ELECTRIC

STOP CLOCK

Because this modern stop clock is too big to be carried in one's pocket, it cannot easily become mislaid or lost—you know where it is when you want it.

Because of its rugged construction, it stays out of the repair shop.

Because of its large face, it is easy to read. Will measure elapsed time down to 1/200th of a second. Has handy remote control switch.

Every laboratory should be equipped with this precision instrument. 30 days free trial. Write for details.

THE STANDARD ELECTRIC TIME CO.

Springfield, Massachusetts

BRANCH OFFICES IN PRINCIPAL CITIES

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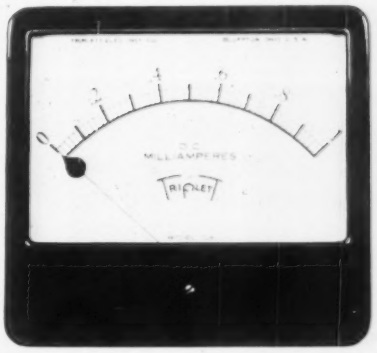

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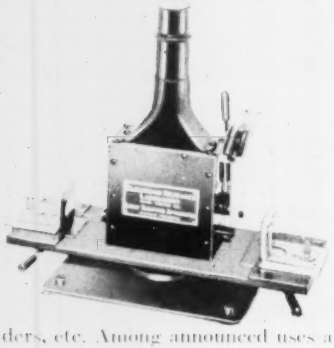

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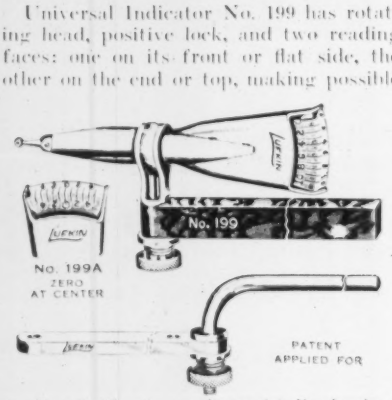

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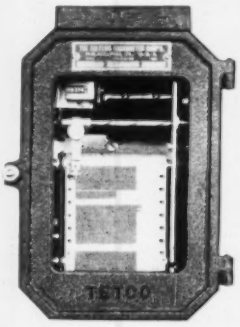

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Statement of the Ownership, Management, Circulation, etc., Required by the Act of Congress of March 3, 1933, of *Instruments* published monthly at Pittsburgh, Pennsylvania, for October 1st, 1938.

State of Pennsylvania, County of Allegheny, ss.

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Richard Rimbach, who, having been duly sworn according to law, deposes and says that he is the Publisher of *Instruments* and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, embodied in section 411, Postal Laws and Regulations, to wit:

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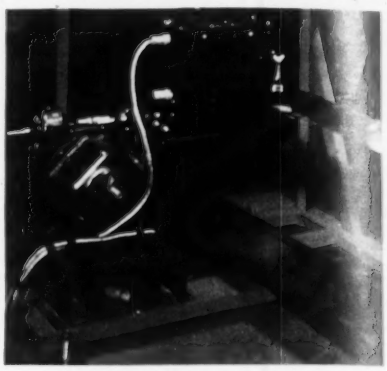

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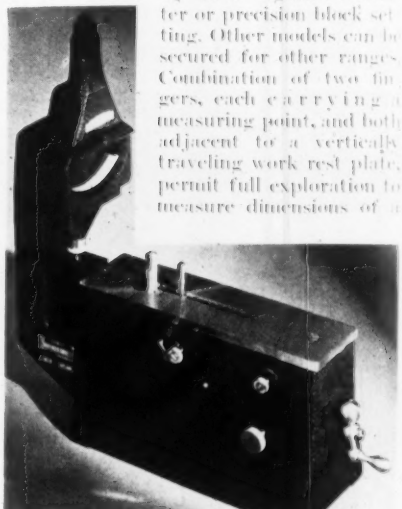

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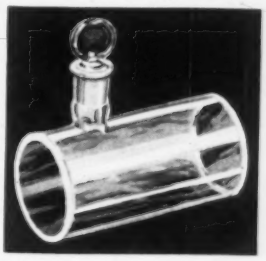

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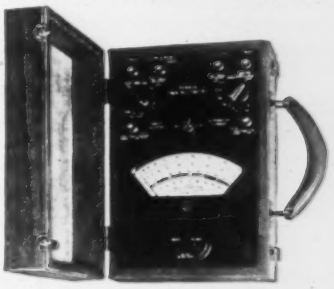

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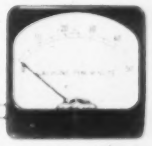

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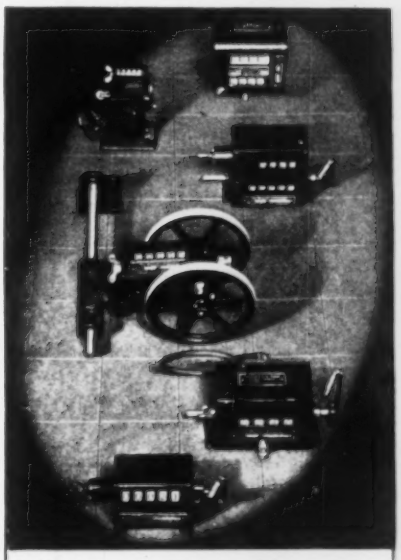

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Temperature-sensitive Magnetic Alloys and Their Uses

By L. R. JACKSON and H. W. RUSSELL
Metallurgist Chief Physicist
Battelle Memorial Institute, Columbus, Ohio

TO meet the demand for accurate temperature control, temperature-sensitive properties of materials have been utilized. Among these properties, one peculiar to ferromagnetic materials has not yet received much attention—that is the variation in magnetic permeability with temperature.

About 1600, Gilbert discovered that iron loses its magnetism when red hot. Later quantitative investigations have established that this loss of magnetism in iron occurs over a range of temperature terminating at about 780° C. (1436° F.). For the other two ferromagnetic elements, nickel and cobalt, similar effects occur at 352° C. (665° F.) and 1120° C. (2048°F), respectively. These critical temperatures are called the Curie points of the corresponding metals. The drop in permeability with increasing temperature for these metals is only large enough to be useful over a temperature range starting about 50° C. (90° F) below their respective Curie points; thus it is obvious that the three isolated ranges represented in nickel, iron, and cobalt, are insufficient to permit the design of devices sensitive to arbitrarily chosen temperature ranges. To open the field for such design, there should be available materials having any specified Curie point.

It has been known that it is possible to modify the Curie point by alloying; however, all alloys having the same Curie point are not equally desirable and the purpose of the investigation to be described here was to discover the most suitable alloy system. In the course of investigating various alloy systems a number of devices were built to demonstrate the properties of the alloys. In order to present a more concrete picture of the uses of temperature-sensitive magnetic alloys, a few of these devices will be described briefly before the properties of the alloy system finally chosen are presented in detail.

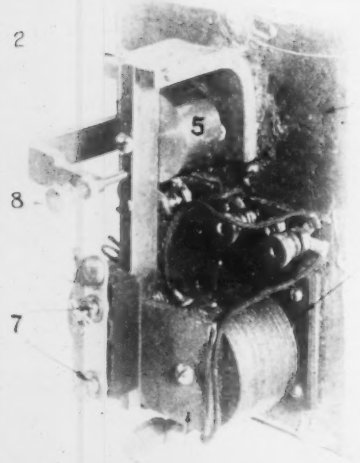


Fig. 1. Contactor Utilizing Low Curie Point Alloys for Controlling the Temperature of a Vertical Surface.

1—Copper base.

2—Pivot suspension.

3—Eight laminations of low Curie point alloy.

4—Top of horseshoe formed by eight laminations of No. 24 silicon transformer sheet.

5—Counterweight used to adjust restoring forces.

6—Electrical contact.

7—Springs used to adjust contact pressure.

8—Air gap adjustment.

Temperature-sensitive Contactors. Fig. 1 illustrates a temperature-sensitive electromagnetic contactor using an alloy having its Curie point at about 200° F. as an armature. Heat is transmitted to the alloy through the copper base shown; the rest of the illustration is self-explanatory. By manipulating the restoring force on the contactor, it could be made to operate at any temperature desired between about 160° F. and 190° F., in the case of the particular device illustrated. Such a contactor is useful for thermostated surface temperature.

Temperature-sensitive Reactors. A reactor made with a core of a temperature-sensitive magnetic alloy can be made to vary its reactance with temperature in a number of ways, depending on the circuit in which it is used. Fig. 2 shows the types of response which can be obtained and a schematic wiring diagram.

When there is no capacitor in the circuit, the reactance varies according to curve 1 of Fig. 2. When a condenser, having a capacitive reactance X_c greater than the inductive reactance X_L at all temperatures, is placed in the circuit, then a response such as shown in curve 2 is obtained. If the value of X_c is adjusted so that resonance occurs for some value of temperature, then the type of response shown in curve 3 is obtained. A reactor of this kind has been used to operate small fan motors and to open and close relays of various sorts. Such a reactor would also be useful in time-delay devices, since the mass of temperature-sensitive alloy could be made large enough to require appreciable time before a desired response is obtained.

Temperature-sensitive Transformers. A transformer whose secondary output depends on temperature was made by winding the secondary on a core of temperature-sensitive magnetic alloy as illustrated schematically in Fig. 3. In this type of transformer the secondary output drops with increasing temperature. This type of characteristic is opposite to that obtained from the reactor described above with no condenser in the circuit.

Since in this type of transformer the primary and secondary are wound on separate legs leakage reactances are rather high. The effect of these high leakage reactances on operating characteristics can be minimized by placing a capacitor in the secondary circuit. The capacitor has the effect of supplying magnetizing current to the secondary and thereby increases the output to such an extent that transformers of this type can be used to operate small motors and other electrical equipment without the use of auxiliary relays.

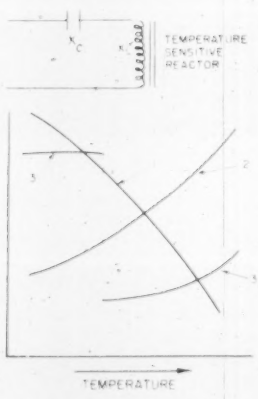
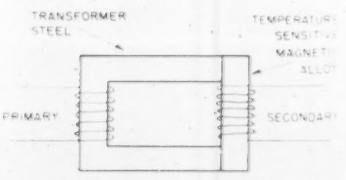


Fig. 2. Response of Temperature-sensitive Reactor under various Circuit Conditions.

Fig. 3. Schematic Diagram of Temperature-sensitive Transformer.



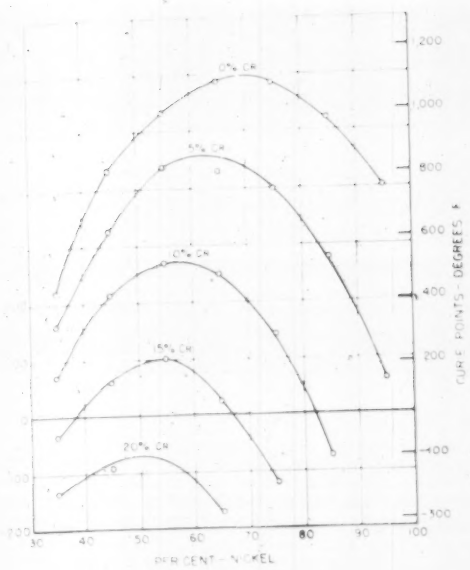


Fig. 4. Curie Point of Fe-Ni-Cr-Si Alloys.

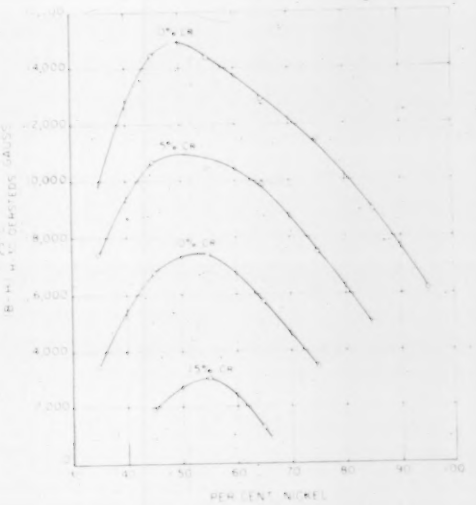


Fig. 5. Magnetization Values of Fe-Ni-Cr-Si Alloys at T = 25° C. H = 30 oersteds.

DEVELOPMENT OF TEMPERATURE-SENSITIVE MAGNETIC ALLOYS

Factors considered in choosing the most suitable alloy system containing alloys having their Curie points at various temperatures were the following:

1. The alloy should not be unduly sensitive to slight variations in composition. The inevitable difference in two separate melts of the same nominal composition should not result in a large difference in the Curie points.

2. The Curie point should be independent of heat-treatment and should be the same for rising and falling temperatures.

3. The alloys should be capable of being formed into sheets or other shapes by rolling or forging.

4. The permeability at temperatures below the Curie point should be as high as possible.

Preliminary investigations on various alloy systems indicated that the quaternary Fe-Ni-Cr-Si system most completely satisfied the requirements. Factors entering into the choice of this system rather than a more simple binary or ternary system can be summarized as follows:

1. In the binary Fe-Ni alloys Curie points below 200° C. are difficult to reproduce because the Curie point is extremely sensitive to slight variations in composition.

2. The ternary Fe-Ni-Cr[1] alloys are more reliable for the reproduction of Curie points because they are not so sensitive to slight changes in composition; but saturation values of magnetization at temperatures below the Curie point are not high enough.

3. The addition of silicon to the ternary Fe-Ni-Cr system has two desirable results. The silicon acts as an efficient deoxidizer and thus aids in rendering the alloys more forgeable. Like chromium, silicon has the effect of depressing the Curie point but it is much more effective than chromium in this respect. The Curie point of a given Fe-Ni alloy is lowered by 1% Si as much as by 4% Cr. Alloys with a given Curie point and containing silicon have somewhat higher saturation values at temperatures below the Curie point than do the Fe-Ni-Cr alloys. There is, therefore, a real advantage in the use of the quaternary Fe-Ni-Cr-Si system.

There are definite limitations to the amount of silicon which can be used. More than 1% Si has a harmful effect on workability and, particularly in alloys containing less than 40% Ni, more than 2% Si introduces another phase with a high Curie point.

In Fig. 4 and 5 are plotted results of tests on the Fe-Ni-Cr-Si alloys. In view of the known effect of silicon in lowering the Curie point of the alloys it was decided to reduce the number of alloys necessary to investigate the system by keeping the silicon constant. This constant silicon content was made 0.3% which is under the 1% value noted above. The fact that the Si content is constant enables the plotting of results to be greatly simplified by lumping the Fe and Si together. Thus in reading Fig. 4, for example, the Ni and Cr contents of a given alloy can be gotten from the curves while the sum of these values subtracted from 100% gives the Fe and Si content.

The alloys were made from commercially available raw material: Armco iron, electrolytic nickel, low carbon ferrochrome and ferrosilicon.

Melts were made in an induction furnace and cast in iron molds in the form of $\frac{1}{2}$" bars 8" long.

Curie points, which were defined as the temperature at which the tangent line of maximum slope on the saturation induction vs. temperature curve cuts the temperature axis, were determined by a ballistic method on the cast bars which were annealed at 1800° F. In order to secure a better length to diameter ratio and avoid a large demagnetizing factor, these cast bars were later hot rolled to $\frac{1}{4}$" diameter and, after an 1800° F. anneal, room-temperature magnetization curves were also obtained by a ballistic method.

Fig. 4 shows Curie points of the various alloys as dependent on composition. The curve for 0% Cr agrees with the well-known data for iron nickel alloys, except for a lowering in Curie point due to silicon.

The ferric induction $(B-H)$ of the alloys at 25° C. (77° F) for a magnetizing field H = 30 oersteds is shown in Fig. 5. This field is sufficient to give a magnetization well above the knee of the magnetization curve for all of the alloys. The curve for 0% Cr, with allowance for the effect of silicon, is in good agreement with values reported by Yensen[2] on pure iron nickel alloys.

Theory[3] indicates that

$$\frac{(B-H)_{sat}}{(B-H)_{sat\ at\ 0°K}} \tanh = \frac{(\theta + 273)(B-H)_{sat}}{(T + 273)(B-H)_{sat\ at\ 0°K}}$$

where $(B-H)_{sat}$ is the saturation magnetization at the temperature T°C. $(B-H)_{sat\ at\ 0°K}$ is the corresponding

[1] Chevenard, *Travaux et Memoires du Bureau International des Poids et Mesures*, Vol. 17, 1927.

[2] Yensen, Magnetic and Electric Properties of Iron-nickel Alloys, *Journal American Institute of Electrical Engineers*, Vol. 45, 1926, Pages 1065-1095.

[3] Bitter, Introduction to Ferromagnetism, McGraw-Hill Book Co., New York, 1937, Page 224.

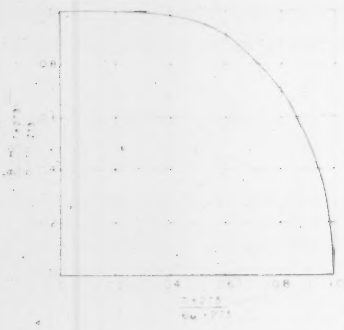


Fig. 6. Temperature Dependence of Magnetization.

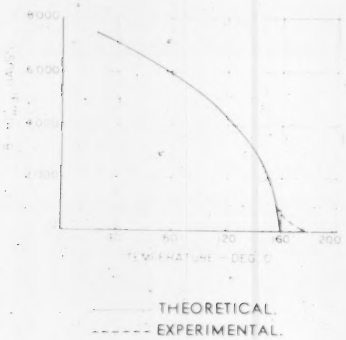


Fig. 7. Magnetism-Temperature Curve. Alloy 35% Ni 5% Cr 60% Fe — Si

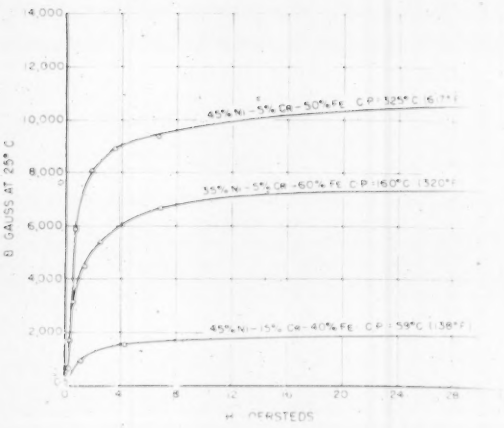


Fig. 8. Room Temperature Magnetization Curves of Typical Fe-Ni-Cr-Si Alloys.

value at the absolute zero, 0° K = −273° C, and θ is the Curie point in degrees C.

Experimentally, this expression has been found to hold not only for saturation values, but also for any value of magnetization well above the knee of the magnetization curve. The general relation is shown plotted in Fig. 6.

A specific example will illustrate how Figs. 4, 5, and 6 can be used to obtain the magnetism-temperature curve of any given alloy.

The alloy having the composition 35% Ni, 5% Cr, 0.30% Si and the rest Fe, from Fig. 4 has its Curie point at 160° C. It should be noted that an alloy containing the same percentages of Fe, Ni, and Cr but without silicon would have a substantially higher Curie point. From Fig. 5, at a temperature of 25° C. and due to a magnetizing field of $H = 30$ oersteds the silicon containing alloy has a magnetization of 7400 gauss, which is one point on the magnetization-temperature curve. Now

$$\frac{T + 273}{\theta + 273} = \frac{25 + 273}{160 + 273} = 0.688$$

Referring to Fig. 6 for this point,

$$\frac{(B-H)_{25^\circ}}{(B-H)_{-273^\circ}} = 0.84 ,$$

Knowing that $(B-H)_{25^\circ} = 7400$, then

$$(B-H)_{-273^\circ} = 7400 \div 0.84 = 8800$$

The value $(B-H)_{-273^\circ} = 8800$ is then used to obtain subsequent points on the curve in the following manner:

At 50° C, $\frac{T + 273}{\theta + 273} = \frac{273 + 50}{160 + 273} = 0.747$

From Fig. 6, at $\frac{T + 273}{\theta + 273} = 0.747$ it is found that

$$\frac{(B-H)_{50^\circ}}{(B-H)_{-273^\circ}} = 0.775$$

Thus, $(B-H)_{50^\circ} = 0.775(B-H)_{-273^\circ} = 6810.$

Other values are obtained in the same manner.

Fig. 7 shows the magnetization-temperature curve obtained by this method. This curve agrees well with experimental data, except at temperatures close to the Curie point. The experimental curve is shown dotted to illustrate deviations.

Since values of magnetization below the knee of the magnetizing curve for any alloy will depend not only on temperature but also on the heat-treatment of the alloys and on other factors such as internal strains, there is no concise method of presenting information about the entire magnetization curve for all alloys. Fig. 8 is shown, however, to give the order of magnitude of what can be expected from typical alloys tested at 25° C. (77° F) in the form of $\frac{1}{4}$" hot-rolled rods which had been annealed at 1800° F.

This investigation was sponsored by the Utilities Co-ordinated Research, Inc. Permission to publish is gratefully acknowledged.

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Elastic Properties as a measure of Hardness

By S. R. WILLIAMS
Professor of Physics, Amherst College

(Continued from September issue)

YOUNG'S MODULUS OF ELASTICITY OR THE MODULUS OF STRETCH

In measuring the modulus of volume elasticity, k, it is not an easy matter to measure the change in volume. As a result another modulus of elasticity is used, called Young's modulus or the modulus of stretch. When a wire is stretched, for instance, there is an increase in the length and a diminution in the cross section which results in a change in volume. The form also changes, making Young's modulus a hybrid modulus. It is Young's modulus which must be determined and studied in the case of the wires which go into the cables carrying our great suspension bridges. It must not only be studied within the elastic limit range but also beyond this range to the value of its tensile strength and to the stress at which the wire actually pulls asunder. See Fig. 27, April 1937 article, for curves of this sort.

Applying Hooke's law to the elasticity of stretch,

$$Y = \frac{\text{Stretching stress}}{\text{Stretching strain}} = \frac{\text{Force} \,/\, \text{Area}}{\text{Elongation} \,/\, \text{Length}}$$

$$= \frac{F}{e} \,/\, \frac{a}{L} = \frac{FL}{ea}$$

Y is Young's modulus, F is the force applied to the stretching or compressing of the test piece, L is the length of the specimen, e is the elongation or the shortening for the force F and a is the cross section of the material. Numerically, Y is equal to the force necessary to elongate a unit length by the same amount. It is assumed, of course, that the cross section would not vary in the process.

The last form of the equation for Young's modulus can now be put to the experimental test by means of the apparatus shown in Figs. 166, 167 and 168. This device for measuring Young's modulus consists of two 2-inch gas pipes about 12 feet long, bolted to two pieces of angle iron, one at the top and the other near the bottom, Fig. 166. The angle irons in turn are fastened to the brick wall by means of lag bolts. At the center of the top angle iron a good clamp is screwed firmly into position and from this clamp two wires of the same material to be tested are dropped downward and connected, one to a fixed mass, m, Fig. 167, and the other to a scalepan, P, for different masses.

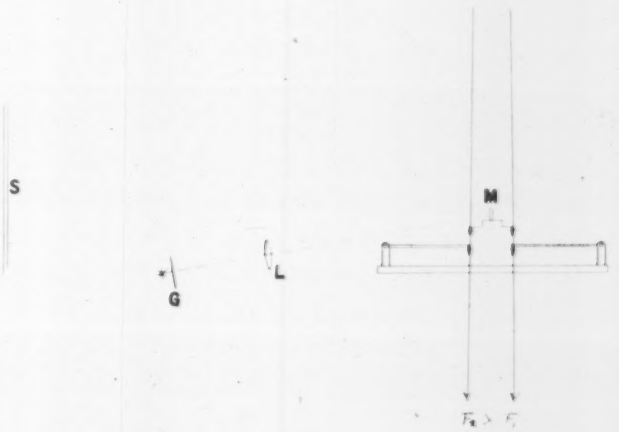

Fig. 168. Arrangement of parts of the apparatus (Fig. 166) for measuring Young's modulus of stretch.

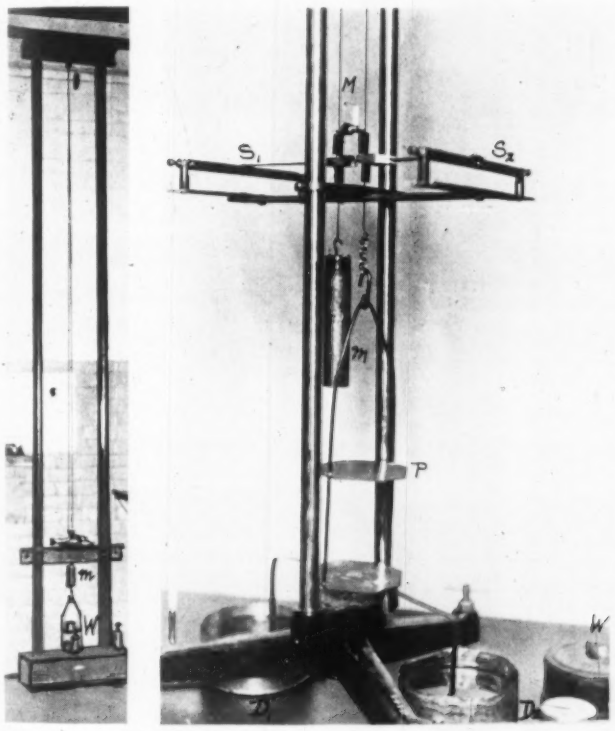

Fig. 166. A framework on which to suspend two strands of wire side by side. One wire is held taut by a constant mass m, while the other has its length varied by the stretching load, W, in measuring Young's Modulus.

Fig. 167. A close-up of mirror, M, scalepan, P, and dashpots, $D_1 D_2$ used in measuring the elongation of a wire when weights are added to the scalepan. The wires extend upwards to a length of about 10 feet and are held by a common chuck in the steel supporting frame.

Merely as guides and stays, two T shaped arms, S_1 and S_2, supported on agate bearings, keep the two wires at a fixed distance apart and without the power to twist around in the clamps which hold the wires to the T shaped guides. Small benches are attached to the wires, directly above the clamps, and across from one bench to the other is set a tiny striding mirror on three points of support. As more and more load is placed on P in Fig. 167, the wire attached to P elongates and tips the mirror M. In Fig. 168 is shown the optical arrangement whereby the change in length with varying load may be determined. The length L is measured between the little benches on which the mirror sits and the lower end of the chuck which holds the upper ends of the two wires. The diameter, $2R$, is measured by means of a micrometer caliper. This gives us all of the data necessary to determine Y for the material used. Using two wires close to each other eliminates errors due to change in temperature. Furthermore, if the upper support sags, both wires move down together and no differential effect is observed.

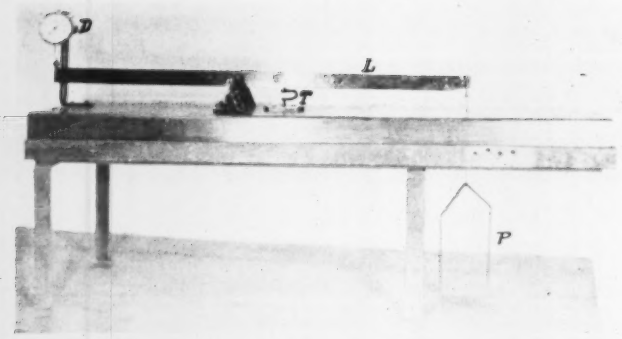

Fig. 169. A lever device used in measuring the hardness of springs by the amount of their bending.

These different moduli of elasticity are introduced at this point because the picture we obtain of what is going on when the distance between the atoms, molecules or particles composing a body varies, will be the picture of what occurs when a ball indenter penetrates the surface of a specimen to be tested for hardness. If a small load is put on the indenter, no permanent indentation occurs. The elastic properties of the material bring about a complete return of the surface to its original form. If a large load is applied permanent deformation is produced: the elastic limit has been exceeded and we have a permanent imprint whose diameter is to be measured for the Brinell number. Both forms of elasticity have been invoked in producing the imprint of the steel ball indenter. In the study of elasticity and of hardness we are dealing with the interatomic and intermolecular forces and the greater these forces are the greater, in general, will be the hardness of the material. By the same token, the greater these interatomic and intermolecular forces are, the greater, in general, will be all of the moduli of elasticity.

Other factors, however, will enter to make an apparent contradiction to this generalization. Unless in some way we can interpret into our hardness numbers more of the physics of elasticity we shall not progress in hardness measurements as a real art.

It would seem that a line of actual advance could be made in the art of hardness testing if we turned more to instruments fundamentally employing elastic properties as a means for measuring hardness, or better, the suitability of a material for a given purpose. Many of the laboratory manuals for the physics laboratory contain directions for using the bending of bars (rectangular cross-section) in the determination of Young's modulus.[1] Some years ago the author was asked to advise regarding a method for measuring the hardness (suitability) of some small springs for a specific purpose. They were strips of flat steel bent into a U-form. The ordinary penetration method for measuring hardness appeared unsuitable because in the heat treatment of the springs they had been given an unusual process which left them extremely inhomogeneous, so far as hardness was concerned. If hardness was to be used as a measure of suitability it became evident that the method must be one which integrated the hardness, *i.e.*, measured the average value for the entire spring. Fig. 169 shows the final machine adopted for making these measurements. *T* is the spring, in position to be tested: so arranged that its prongs can be compressed toward each other by means of the lever *L*. Notches in the ends of the spring insured the same position for each spring as it was placed in position. The procedure for a constant load test was as follows: The spring was placed in position with no weight on the scale pan. The reading on the indicator dial *D* was set to zero. On placing a kilogram mass on the pan *P*, the spring *T* was compressed, and its deflection measured by the reading of the indicator dial. The harder the spring, the less the compression. By reading the scale backward a number was obtained corresponding to the hardness of the spring.

For purposes of separating poor springs from a group which was supposed to be composed of identical springs, this instrument gave results which checked satisfactorily with those obtained by averaging a great many Rockwell readings taken all over the surface of the springs.

For relative measurements such an instrument may serve a useful purpose in determining suitability. Its chief rôle is to illustrate how much of what passes for hardness measurements is chiefly a hodge-podge of various physical phenomena. Many a manufacturing firm today is using some device which they call a hardness tester for determining the relative values of a certain set of unknown physical properties. It serves their purpose admirably for determining the suitability of their material for certain purposes, but it is not advancing the art of hardness testing in the real sense of the word.

REBOUND METHODS

In the study of the elastic moduli there are static and there are dynamic methods used in measuring the coefficients of elasticity. In the dynamic methods, the measurements are made while the atoms and molecules are going through their displacements. In the static methods the measurements are made after the displacements have occurred. It is in this sense of the words, static and

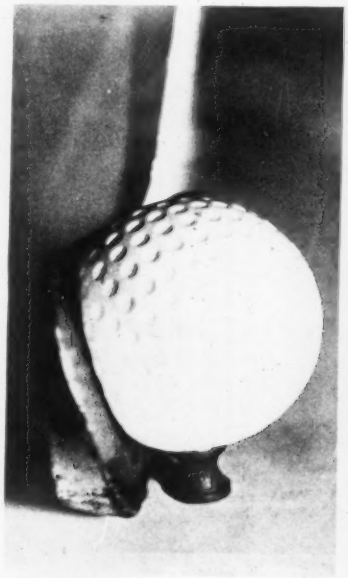

Fig. 170

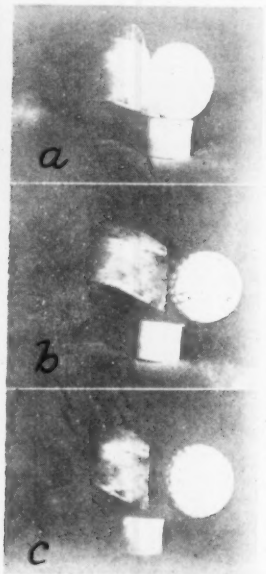

Fig. 171

Courtesy H. E. Edgerton, Massachusetts Institute of Technology

Fig. 170. In the compressed portion of the golf ball the molecules are forced closer together. The elastic properties of the ball cause these to regain their former distances apart, which drives the ball away from the golf club head.

Fig. 171. This series of photographs show, *(a)* the head of the golf club contacting and compressing the golf ball. Although the head of the golf club follows through, the forces of restitution in the flattened golf ball react so quickly that they drive the ball by a rebound from the rapidly following club as shown in *b* and *c*.

[1] D. C. Miller, Laboratory Physics, 2nd Edition, Ginn & Co., Boston, 1932, Pages 98-99.

dynamic, that one should think of static and dynamic hardness testing methods. While the testers shown in Figs. 106 and 107 (April 1938) were called dynamic testers, they could be called so only from the point of view that the impulse given to the indenter was of a short duration. The diameters of the imprints were measured from permanent deformations after the displacements had occurred.

As an illustration of a dynamic method for measuring the modulus of rigidity may be cited the torsion pendulum experiment[2]. A heavy circular disk of known moment of inertia, I, is suspended at the lower end of a small metal rod and with their axes coincident. The upper end of the rod is clamped in a rigid support. When the rod is twisted through a few degrees and then released, the disk will go through a series of oscillations in which the period

$$T = 2\pi \sqrt{(I / T_o)}$$

wherein T_o is the moment of torsion of the rod and I is the moment of inertia of the disk. Since n, the coefficient of rigidity, is a function of T_o, we have

$$n = \frac{8\pi LI}{T^2R^4}$$

where L is the length of the rod and R is its radius.

To adopt a real dynamic method for hardness testing means a break with the best definition we have thus far been able to produce, *viz.*, the resistance to a permanent deformation, unless one can find some definite relation between the behavior of a substance below the elastic limit and the behavior after passing the elastic limit. Apparently it is on this assumption that the originators of the various rebound methods have worked. The rebound method rests upon the elastic forces of restitution called into existence when an external force is applied to a body to change the distances between the constituent particles composing the body. Thus in Fig. 170 the head of a golf club is in contact with the golf ball as the player starts the ball in flight. It will be noted that the ball is flattened in an astonishing fashion on the side in contact with the head of the club. This means a decrease in the distances between the molecules of the ball, whose recovery of its original form and volume will be manifest

[2] D. C. Miller, Laboratory Physics, 2nd Edition, Ginn & Co., Boston, 1932. Pages 101-102.

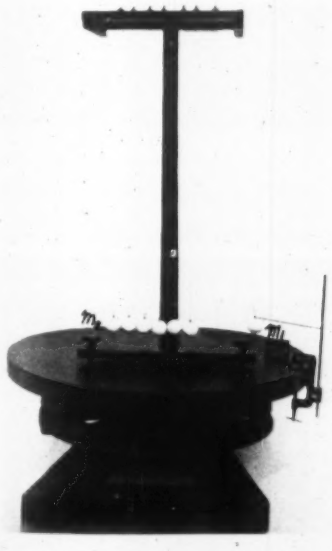

Fig. 172. As the ivory ball to the right strikes the first one, m_1, in the series, a wave of compression runs through the series and the final ball, m_2, is thrown off as was the golf ball from the club.

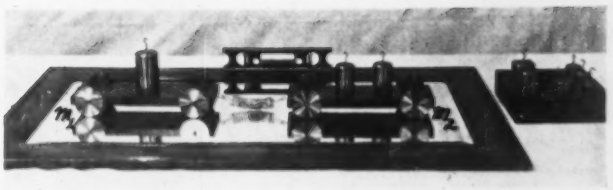

Fig. 173. When the spiral spring is stretched or compressed between the two carts, m_1 and m_2, the latter will be accelerated toward or away from each other. The spring when compressed acts in the same way as the compressed portion of the golf ball between the club's head and the rest of the ball.

in its elastic forces of restitution whereby the molecules in the compressed portion will kick back against the head of the golf club and since action and reaction are equal the ball will be forced away from the club as shown in Fig. 171. The recovery of form and volume is an elastic property which the golf ball possesses in large degree. If the golf ball had been thrown at the golf club head, held in a fixed position, with a velocity with which the golf ball leaves the head of the club, the same compression and elastic recovery would have occurred.

Fig. 172 will illustrate this rebound principle which is so important in some methods used in measuring hardness. Let the ivory ball, m_1, to the right of the figure, be held off to one side by a fine thread. When everything is quiet, burn the thread and the ball will fall and strike the series of equal sized balls. All will remain at rest except the last one to the left, m_2, which flies off to about the same distance as that held by the one to the right originally. The ball at the right had a velocity v_1 when it struck the row of balls and its momentum was m_1v_1. The ball at the left went off with the same velocity since it was thrown to the left (approximately) as far as the one to the right was held originally. The momentum in each case is such that

$$m_1v_1 = m_2v'_2 \ ,$$

or,

$$v_1 = v'_2, \text{ when } m_1 = m_2 \ .$$

This relation is known as the law of the conservation of momentum.

Fig. 173 shows two carts which have a spiral spring between them which may be compressed or stretched as the case may be. One cart may represent the golf club head and the other the golf ball. When the spring is compressed, the recoil of the spring will drive the carts apart just as the golf ball and the club were separated by the recovery of the compressed portion of the ball shown in Fig. 170.

The force accelerating a mass is measured by the rate of change of momentum of that mass. The mean force acting between two impacting bodies is the total change in momentum of either body, divided by the time they are in contact with each other. It would be difficult to measure the period of contact, so attention is usually directed to the total change in momentum which each body experiences by virtue of the impact. This quantity is called the impulse of the force which will be represented by the letter R $\quad$ Ft.

This principle may now be applied to the case of the two carts in Fig. 173 where each cart is thrust against the other so as to compress the spring between them. The two carts have masses, m_1 and m_2, respectively.

Just the instant before impact, m_1 and m_2 have velocities, v_1 and v_2, respectively and at the instant just after impact the corresponding velocities are v'_1 and v'_2. Since